eRD15
Compton electron detector R&D

EIC R&D meeting

January 26-27th 2017

Alexandre Camsonne

eRD15 : Compton electron detector R&D

- Requirement
  - 1% or better electron polarization measurement
  - Best measurement Compton electron detector at SLD (~0.5%)
- Deliverables
  - Simulation to determine signal to background for JLEIC baseline Roman Pot and expected accuracy
  - Detector R&D for faster detector (signal at least shorter than 100 ns for eRHIC design, improves rate capability for JLEIC)
  - Test stand at JLab to measure precision polarization with the foreseen detector for EIC

Deliverable estimate for FY 2017

- Simulation
  - Implement beam pipe in magnet
  - More cross check with old simulation
  - Full simulation with Interaction Region and beam pipe
  - Run simulation large scale on batch farm will full setup
  - Halo modelling
  - Model beam laser interaction
  - Implement polarization extraction analysis
  - Study of systematics and optimization of the setup
  - Synchrotron radiation study, detector response to synchrotron photons
- Wakefield Higher Order Mode
  - Run first pass simulation and determine if Roman Pot is doable for Compton Electron detector
- Test stand
  - Procure Amplifier and SAMPIC and setup bench
  - Measure detector pulse width on the bench

In boxes, completion expected for January 2017 R&D meeting

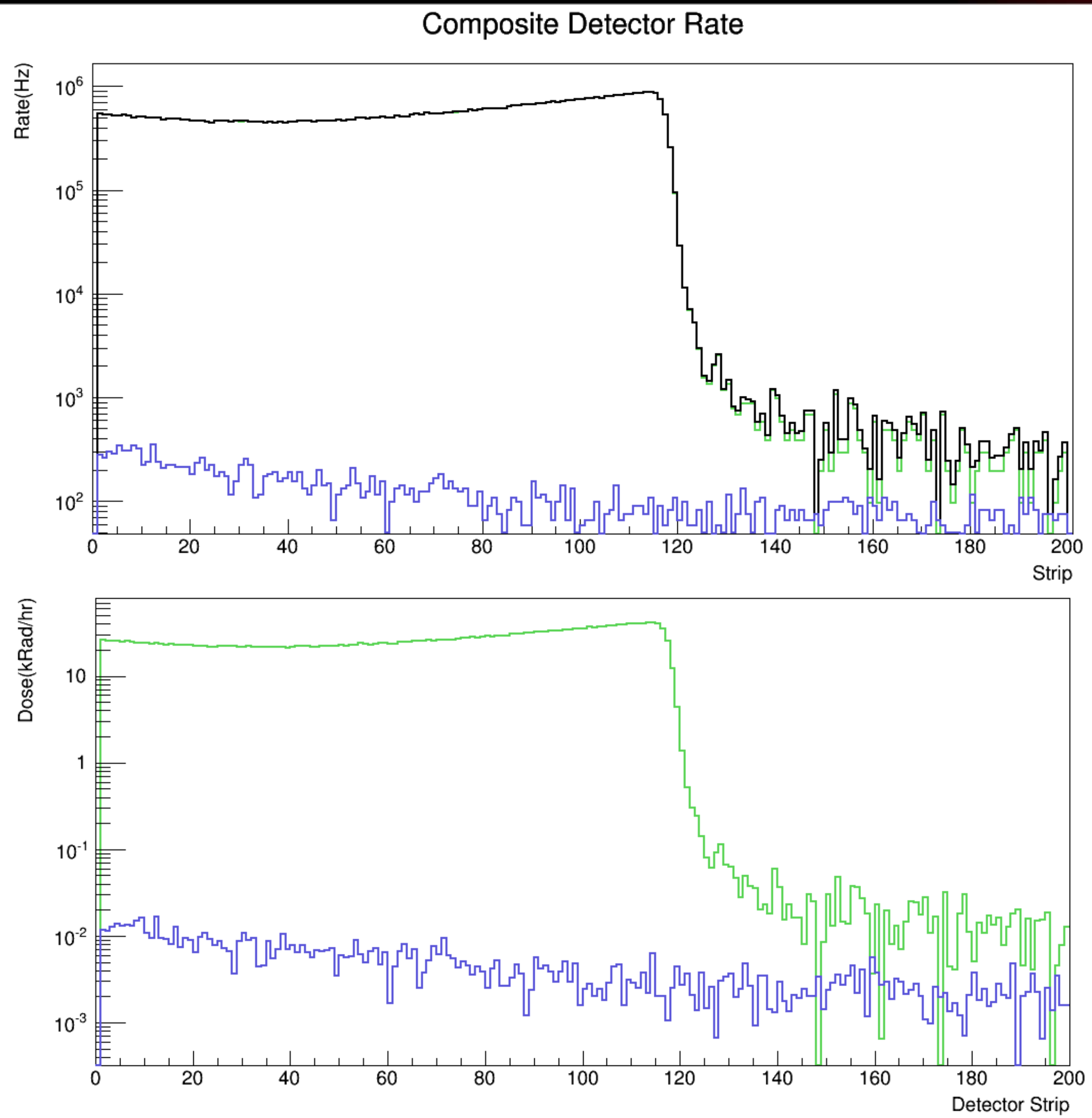
Completed January 2017

- Simulation
  - Implement beam pipe in magnet
  - More cross check with old simulation ➔ GEMC framework validated
  - Full simulation with Interaction Region and beam pipe
  - Run simulation large scale on batch farm will full setup
  - Halo modelling
  - Model beam laser interaction
  - Implement polarization extraction analysis
  - Study of systematics and optimization of the setup
  - Synchrotron radiation study, detector response to synchrotron photons
- Wakefield Higher Order Mode
  - Run first pass simulation and determine if Roman Pot is doable for Compton Electron detector ➔ yes
- Test stand
  - Procure Amplifier and SAMPIC and setup bench
  - Measure detector pulse width on the bench

On going January 2017

- Simulation
  - Implement beam pipe in magnet → Few weeks
  - More cross check with old simulation
  - Full simulation with Interaction Region and beam pipe
  - Run simulation large scale on batch farm will full setup
  - Halo modelling
  - Model beam laser interaction → Few weeks
  - Implement polarization extraction analysis → Modify code for 2 magnets
  - Study of systematics and optimization of the setup
  - Synchrotron radiation study, detector response to synchrotron photons
- Wakefield Higher Order Mode
  - Iterate simulation and improve Roman Pot performance for Compton Electron detector
- Test stand
  - Procure Amplifier and SAMPIC and setup bench → Order Jan/Feb
  - Measure detector pulse width on the bench

Compton Electron Det. Rates

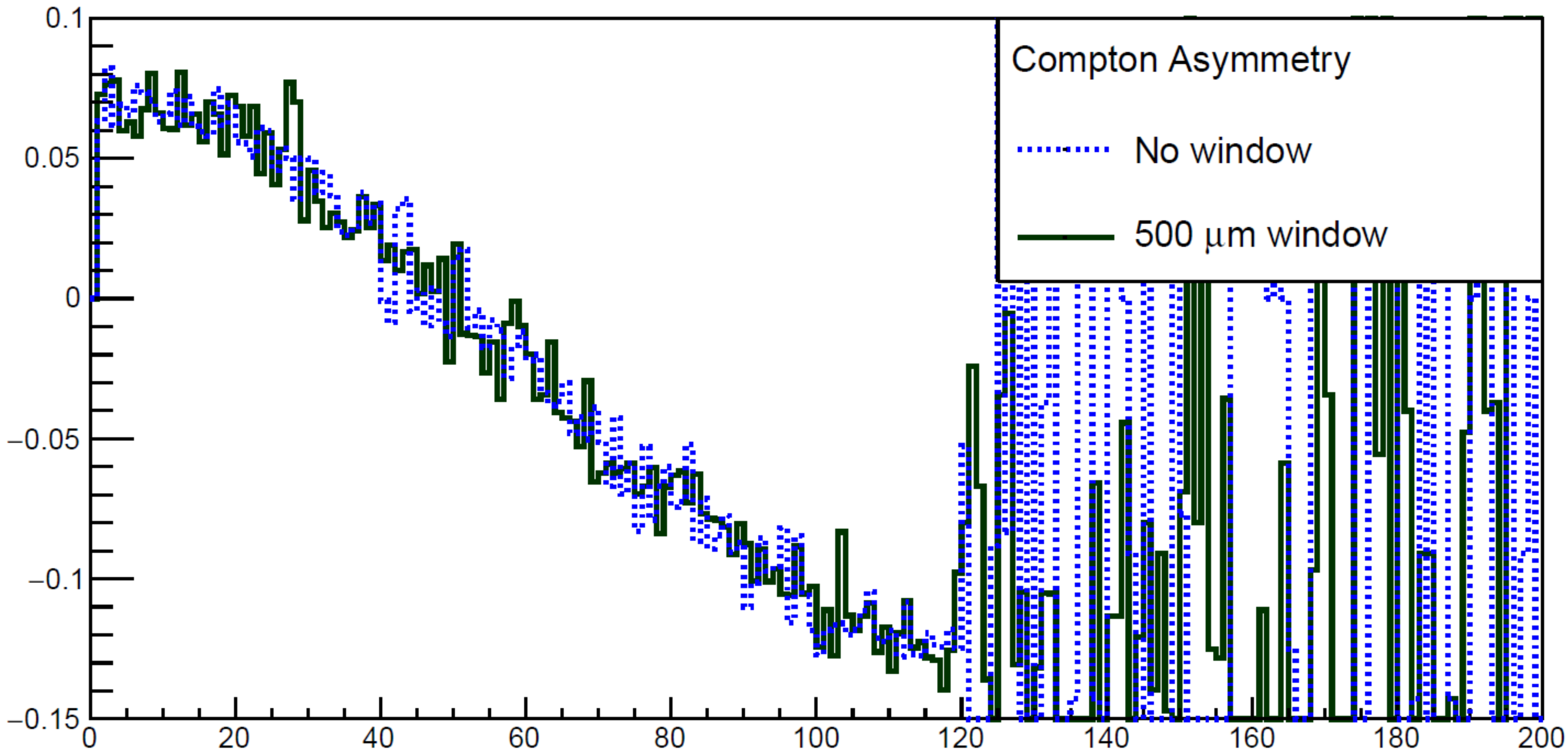


- 10 W
- 1 A of beam
- Green laser

- Compton and Bremstrahlung assuming 10^{-9} Torr

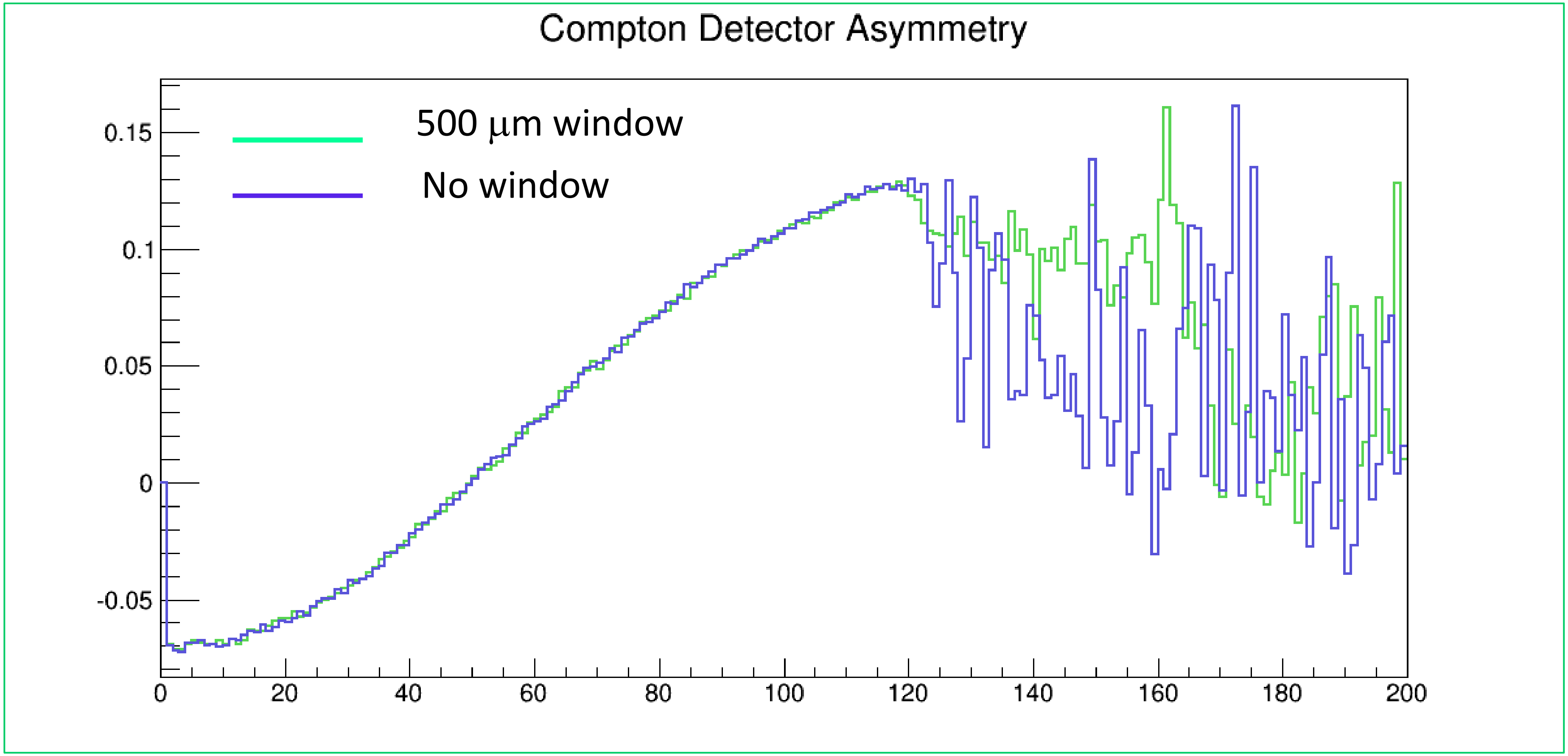
- Corresponding radiation dose

Compton asymmetry with window



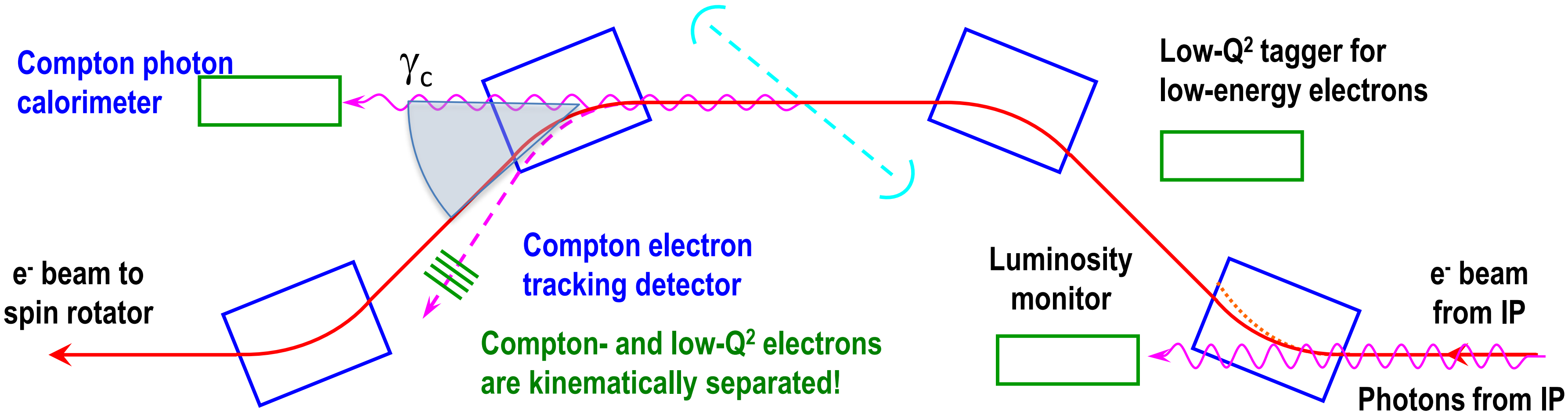
- Roman pot design introduces a 500 μm thin steel window in front of the detector. Preliminary results with low statistics seems to show that there is little change introduced by the window
- To be confirmed with high statistics and polarization extraction analysis

Compton asymmetry with window

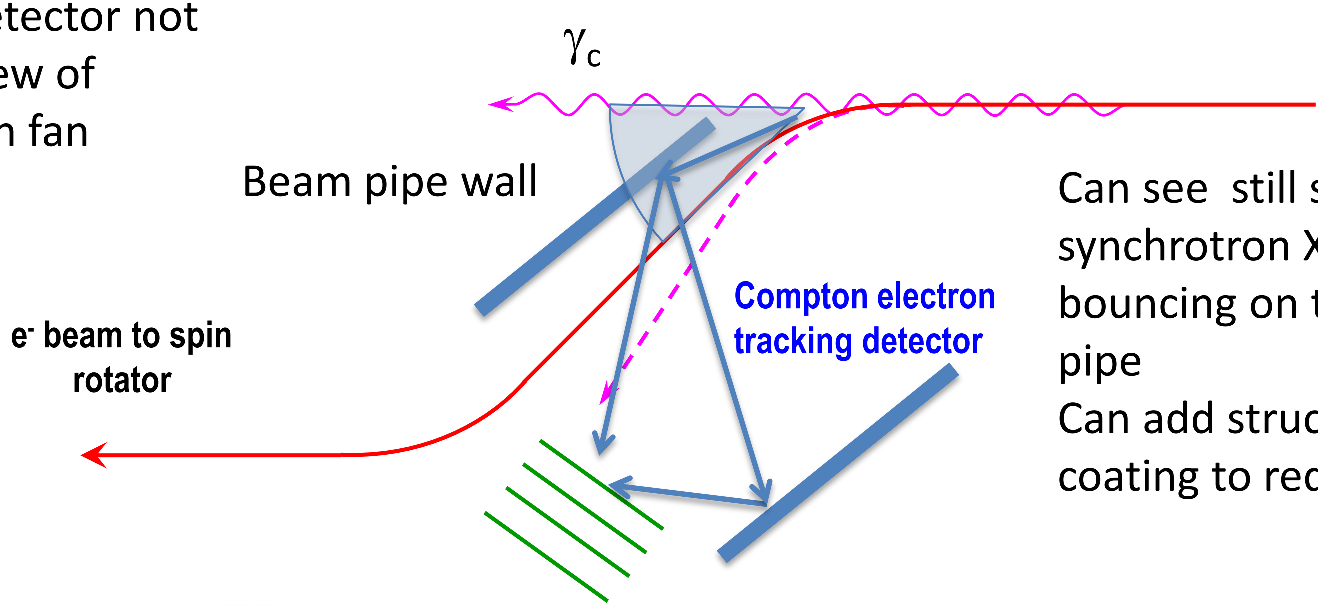


- Higher statistics MC comparison

Synchrotron radiation



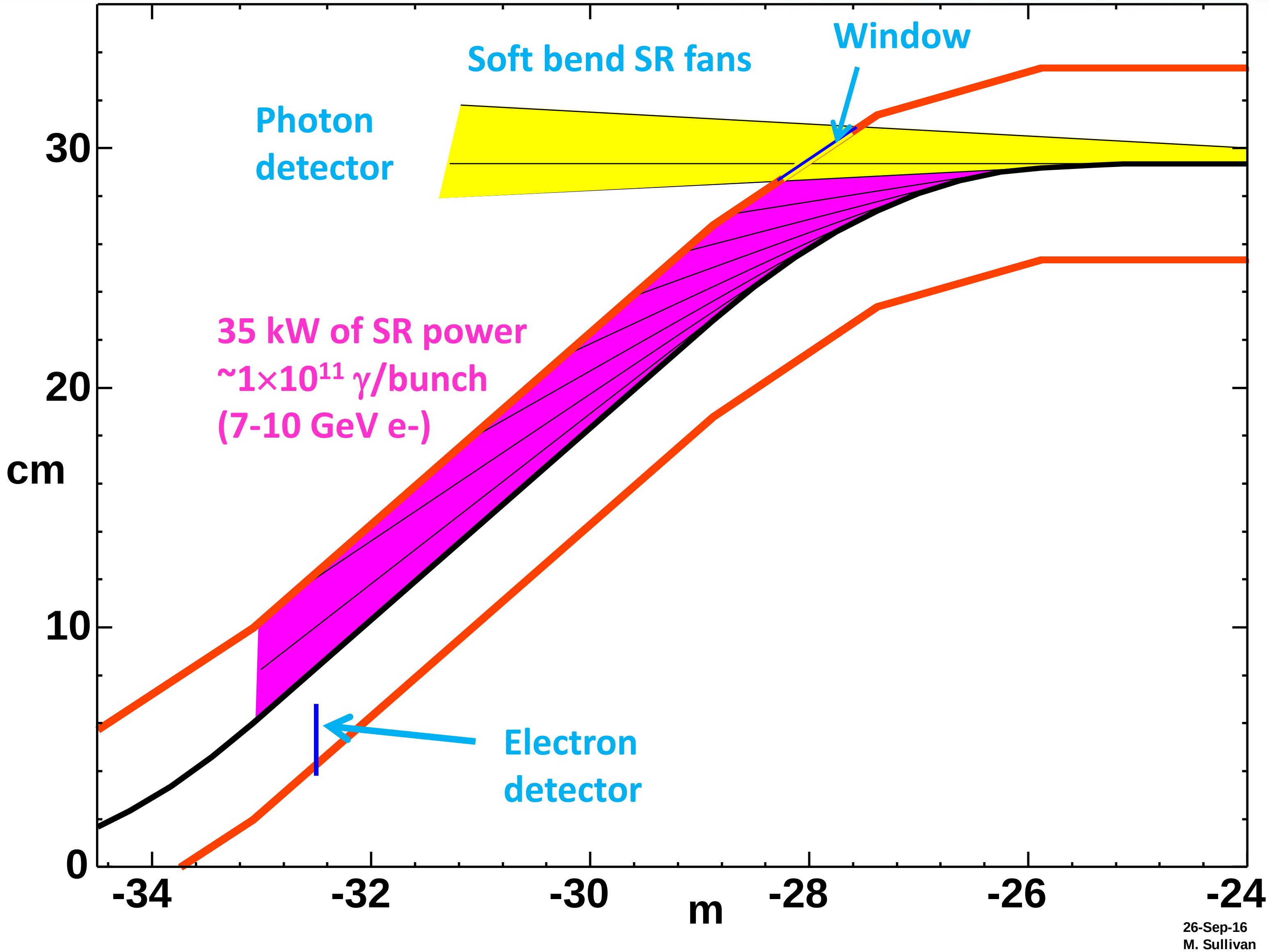
Electron detector not in direct view of synchrotron fan



Can see still see synchrotron X-rays bouncing on the beam pipe

Can add structure and coating to reduce rate

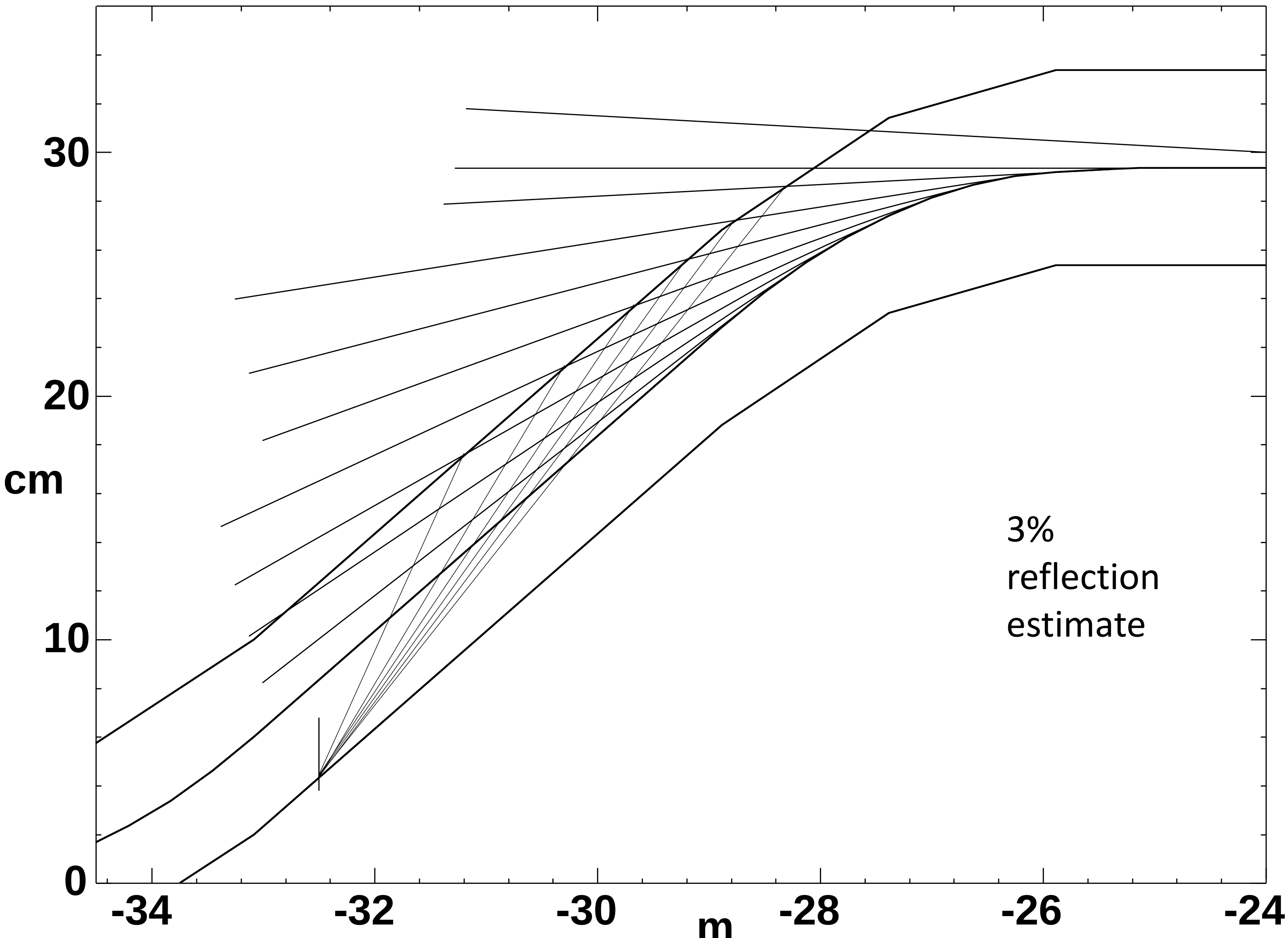
SR fans at Polarimeter Detectors



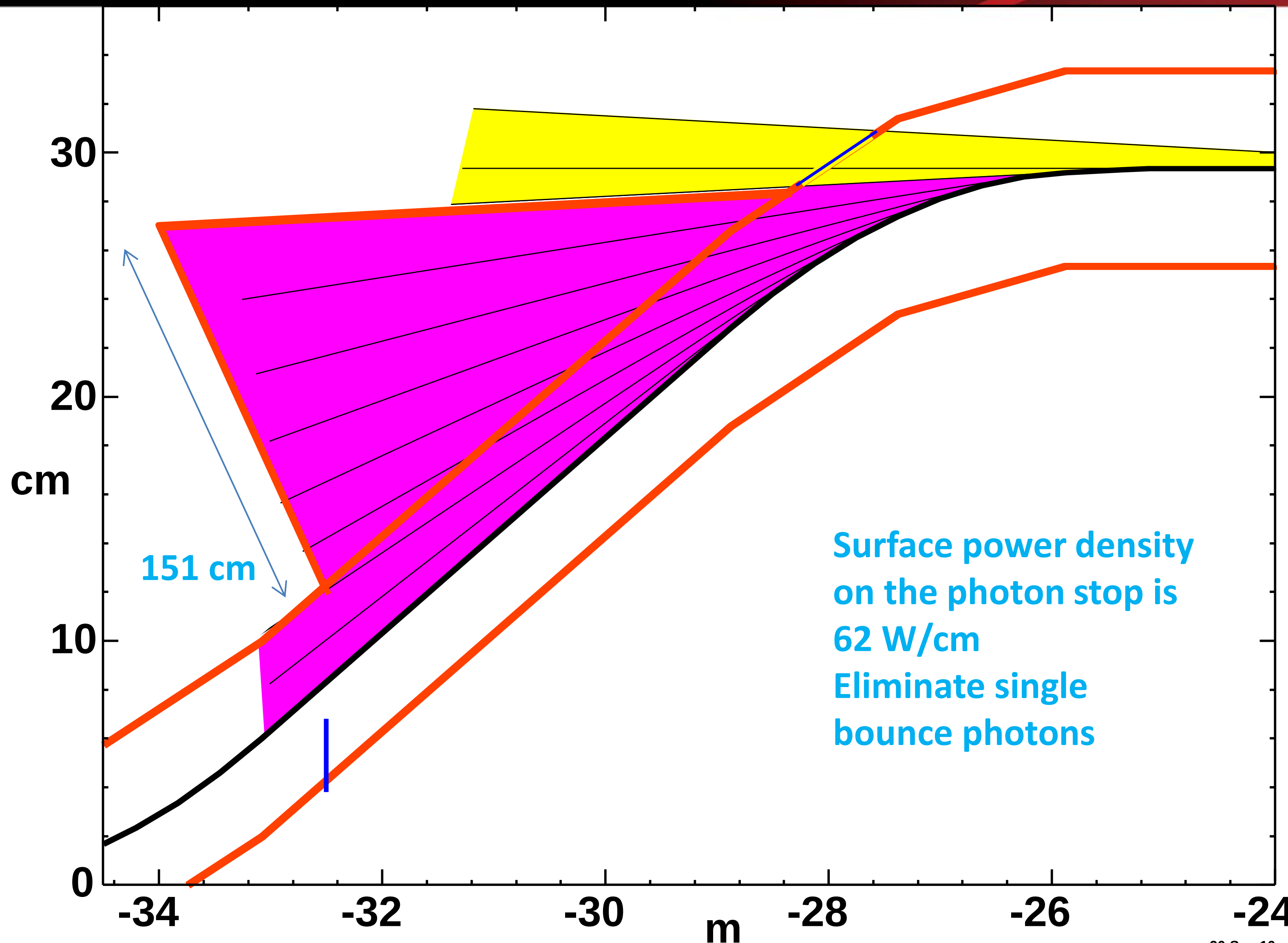
SR photons with one bounce

- The power and the total number of photons /bunch coming from the upstream bend and incident on the upstream beam pipe is:
  - 7 GeV @ 3A 10 GeV @ 0.71A
  - 35.7 kW 35.2 kW
  - 1.60×10^{11} 5.4×10^{10}
- This is a lot of power and a lot of photons
- Assuming a 3% reflection coefficient and…
- Calculating the average SA to the detector…

SR photons with one bounce



Ante-chamber method

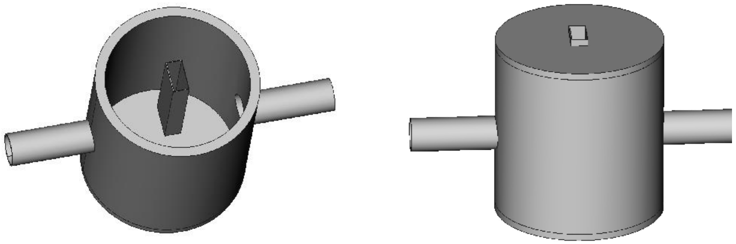


26-Sep-16
M. Sullivan

Synchrotron radiation summary

- Synchrotron radiation power is significant
- Reflected power most likely unacceptable using a standard beam pipe
- Power can be driven out from the detector with a dedicated chamber geometry
- Synchrotron radiation issue solved but might need to study additional radiation from synchrotron induced neutron production

Wakefield progress



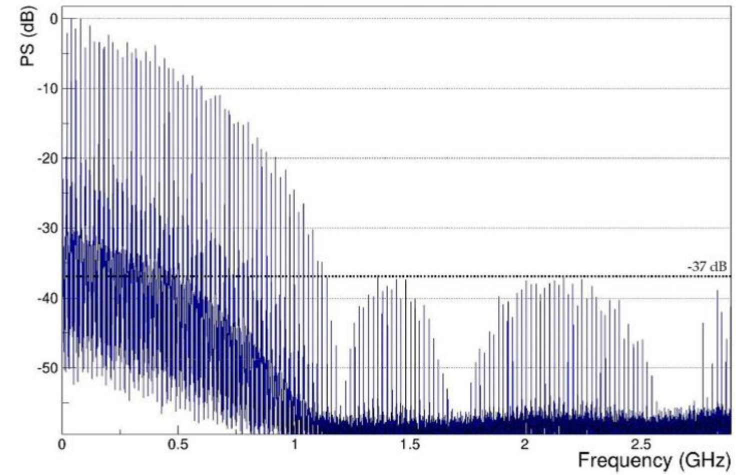
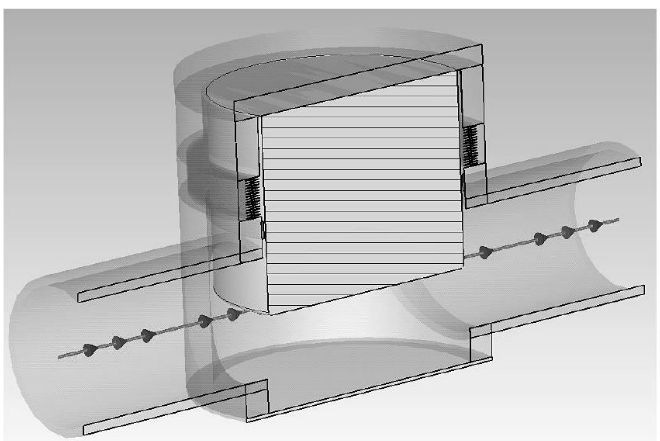


Figure 2.1: *LHC Power spectrum, measured before LS1 [33]. The power spectrum is more than* 37 dB *attenuated above* ~ 1.2 GHz.



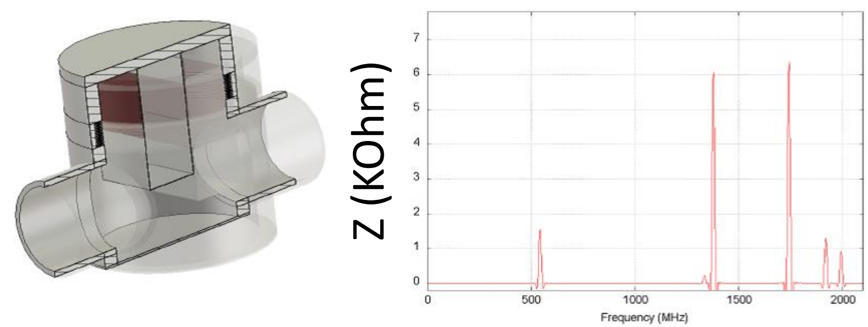
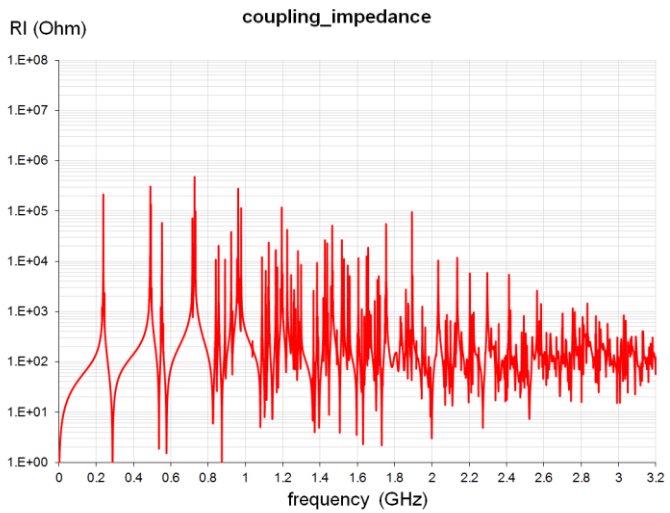
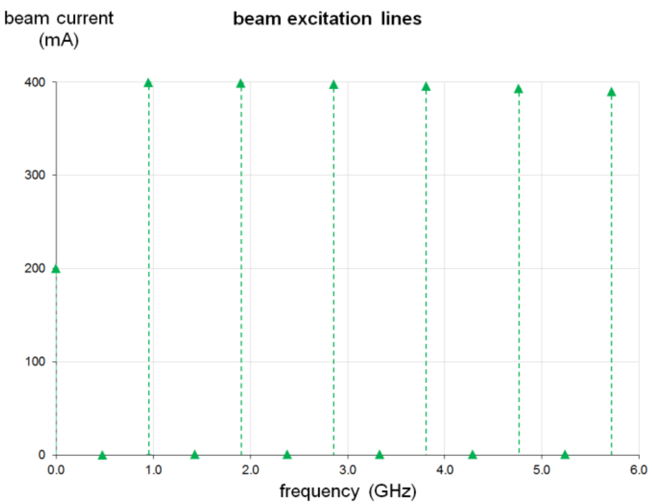
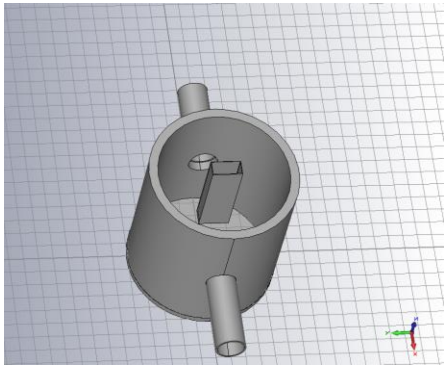


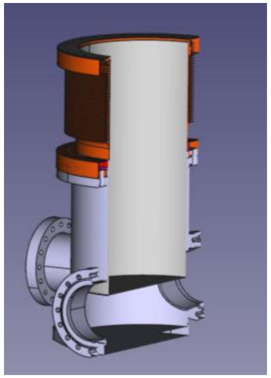
Figure 2.2: *Before LS1 all Totem Roman Pots were box shaped (left). The empty space between the RP and the flange resonate at low frequency* (~ 500 MHz) *as visible in the simulated longitudinal impedance without ferrites (right).*

Wakefield progress (EIC RP)



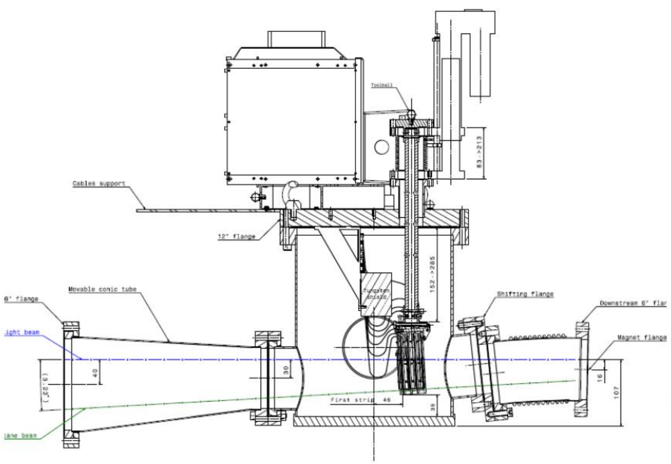


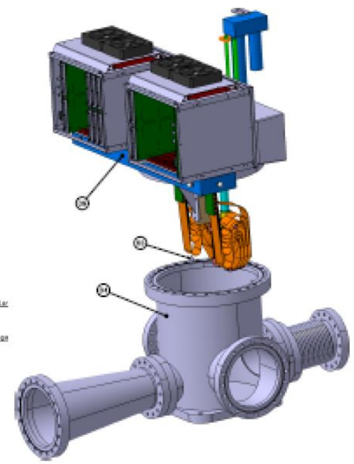


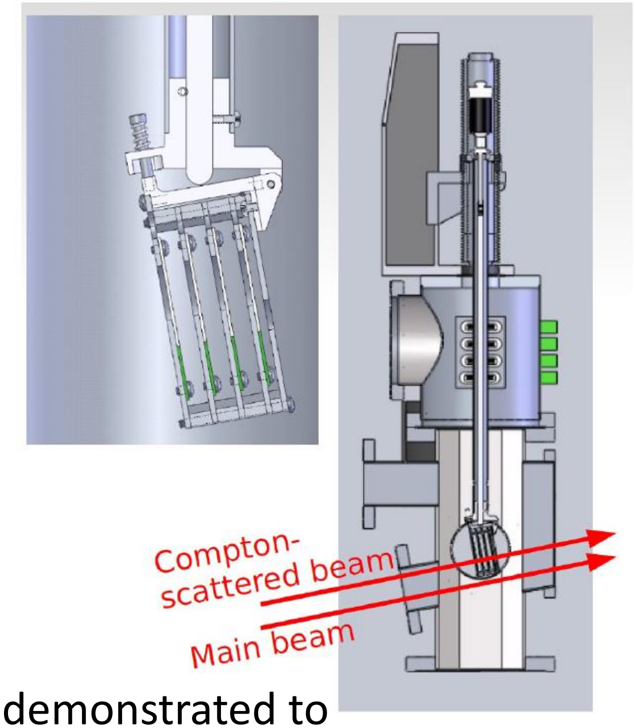


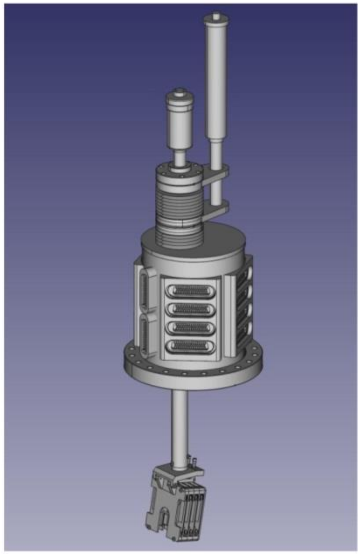
- Impedance evaluation interrupted after 37 hours of computation
- Estimate power deposit
  - 340 W for 0.4 A
  - 2.55 kW for 3 A
- Possible with liquid cooling
- Will work on optimizing geometry
- New CAD model with better geometry
- Request funds for a few months of CST license

Test stand









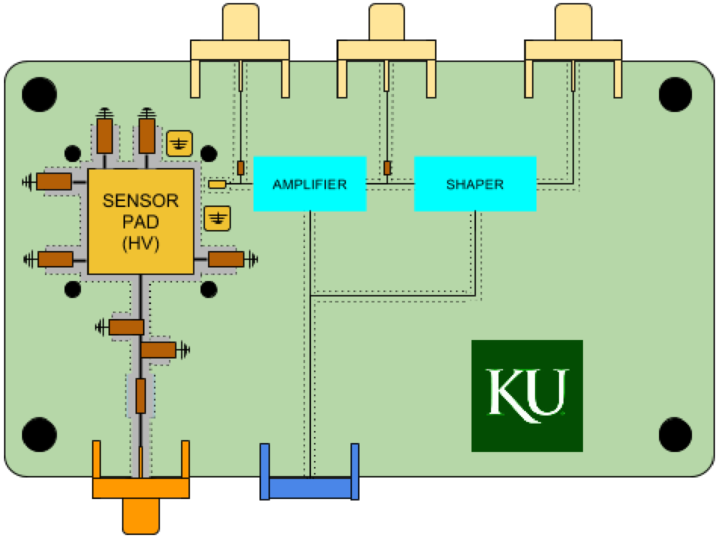
- Compton polarimeter was demonstrated to achieve 1 % systematic with photon at 1 to 3 GeV
- Prove detector technology with pulses shorter than 100 ns eRHIC beam structure
- Crosscheck accuracy of electron detector for EIC

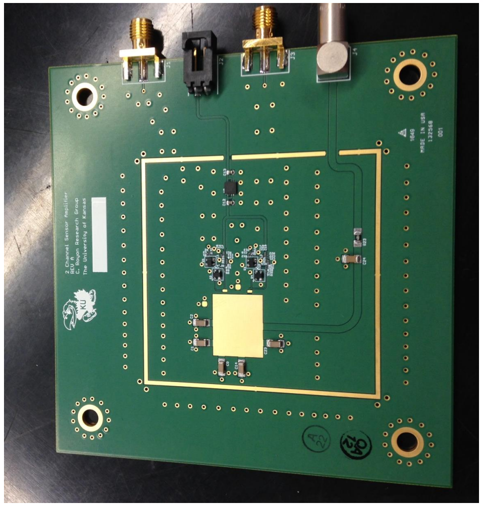
Electronics

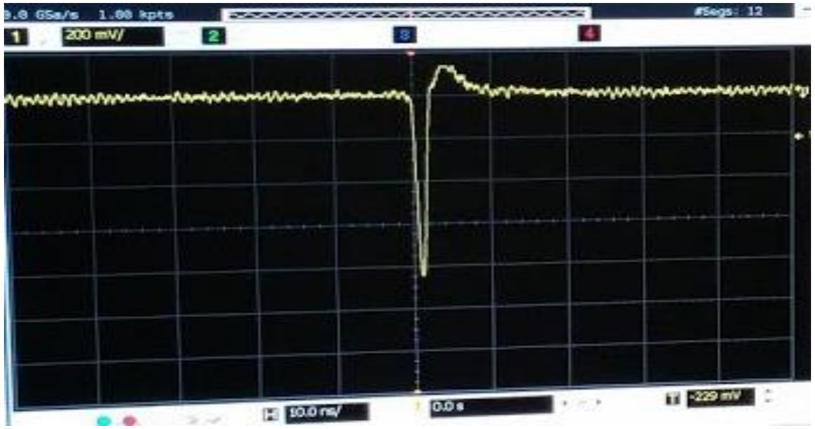
- Available electronics
  - 768 A/D for silicon
  - spare 192 channels
  - 32 channels analog for silicon
  - 256 A/D for diamond
  - 96 spares channels

- Acquired
  - 1 channel of CIVIDEC amplifier
- Will acquire in FY2017
  - SAMPIC
  - 32 channels sampling
  - Up to 8.2 GHz
  - Low cost 4.2 K$
  - Allow study of several channels and record very fast pulses
  - KU working on amplifier design

Amplifier development



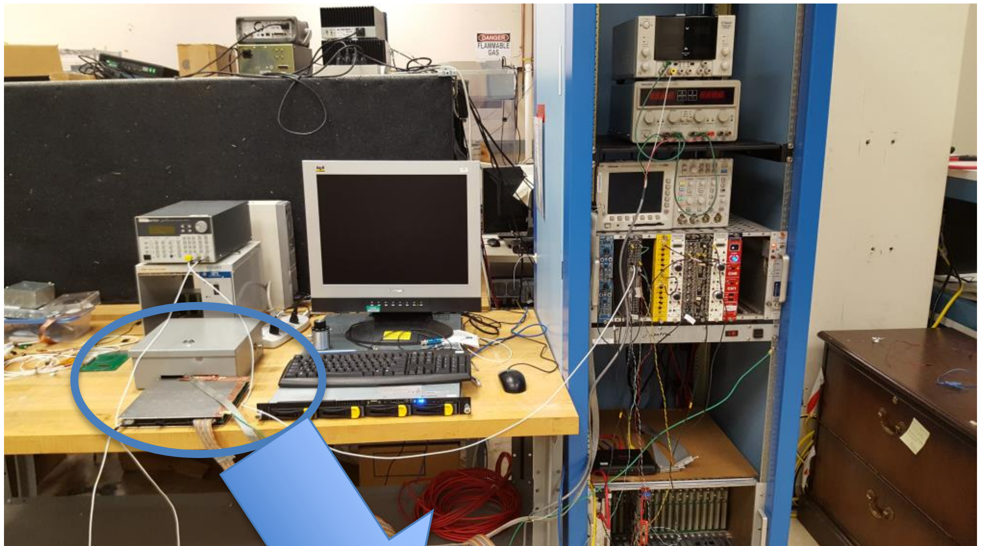


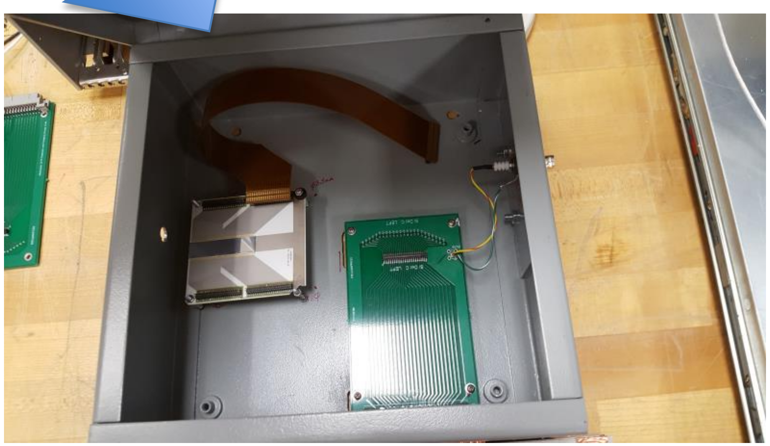


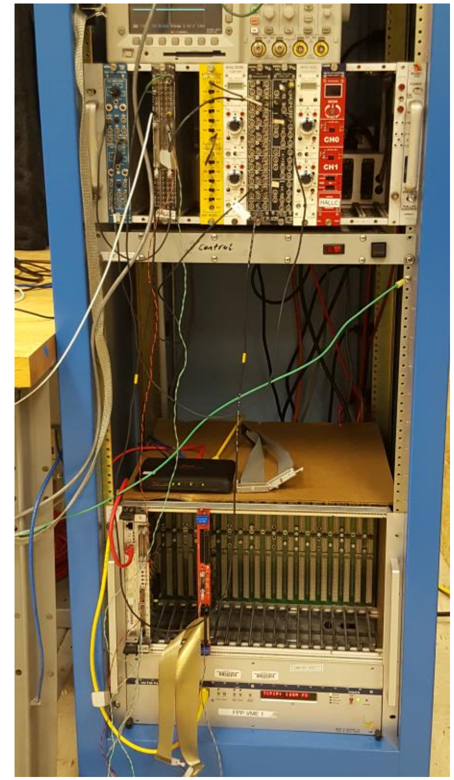
10 ns

- Kansas University single channel amplifier design
- Tested with MCP PMT
- Serve as base for multichannel amplifier

Electronics Test Stand JLab



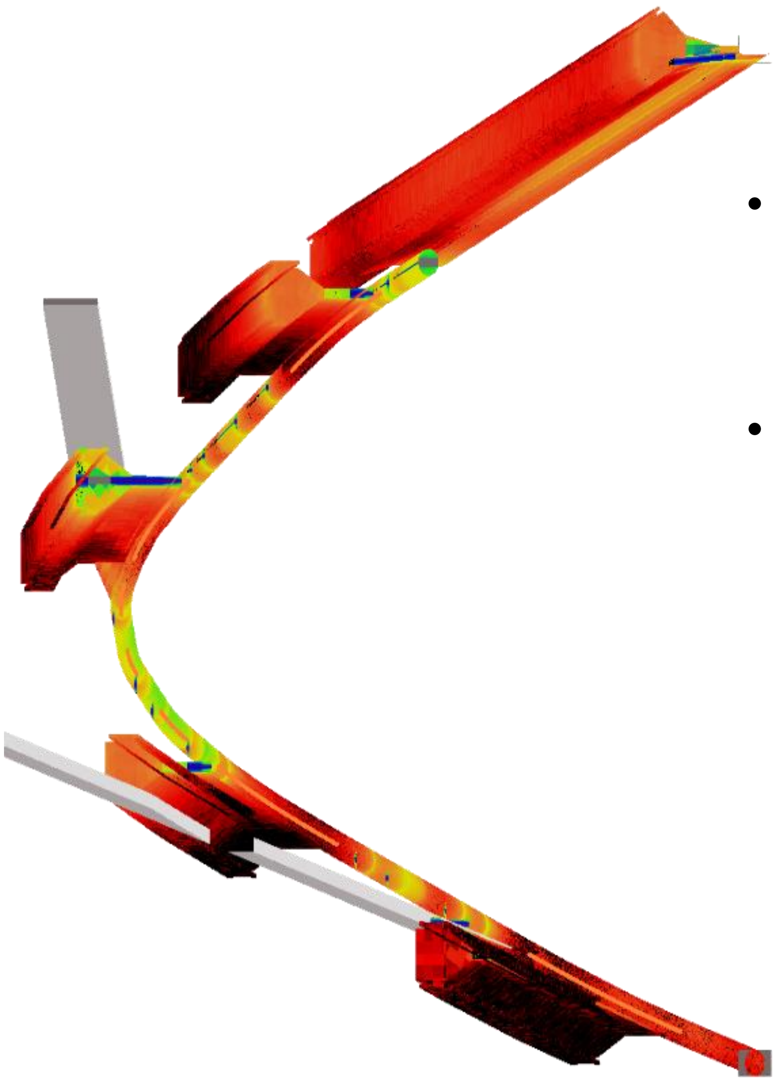




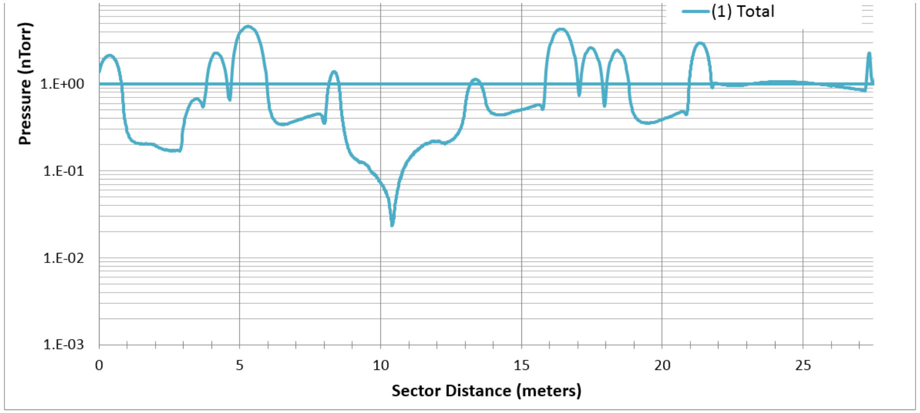
- HV supply
- LV supply
- VME TDC
- Need to work on shielding and grounding

Proposal for FY2018

Modeling available for both static vacuum and Photon Stimulated Desorption

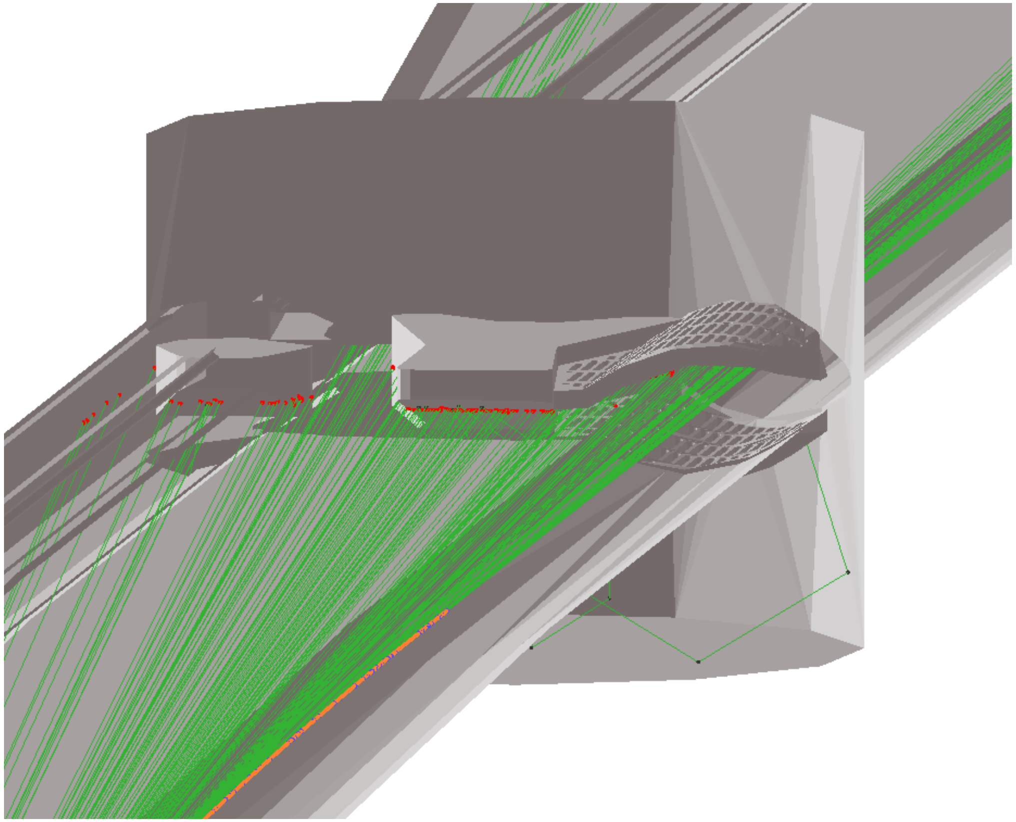


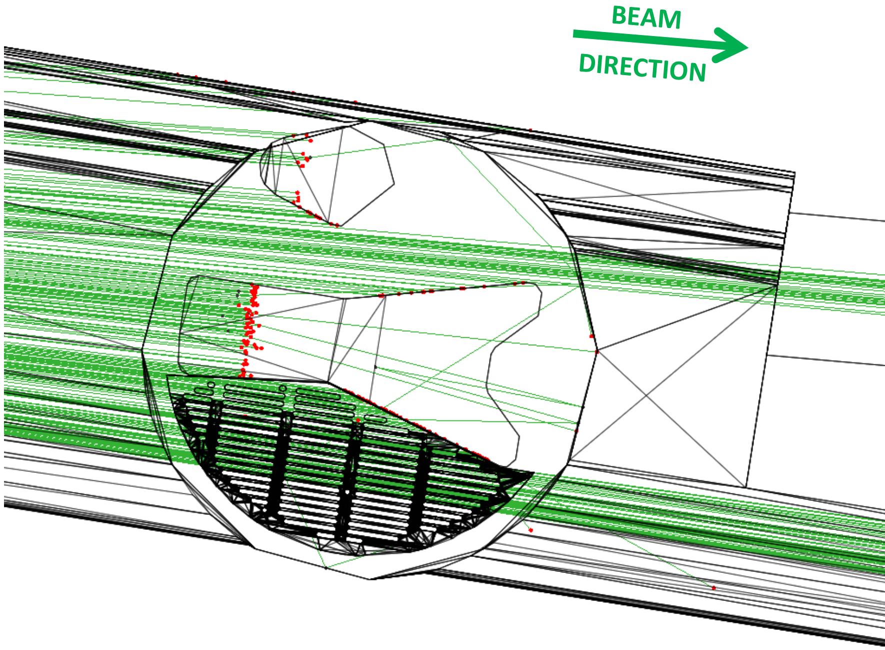
- Molflow+ and Synrad modeling software developed by Roberto Kersevan
- Jason Carter, ANL, used Molflow+/Synrad to model static and dynamic vacuum for APS upgrade
- CAD designs of beamline are combined with pumping speeds and outgassing rates of elements yield expected pressure



How SynRad works

- Magnetic elements generate synchrotron rays within 3D space





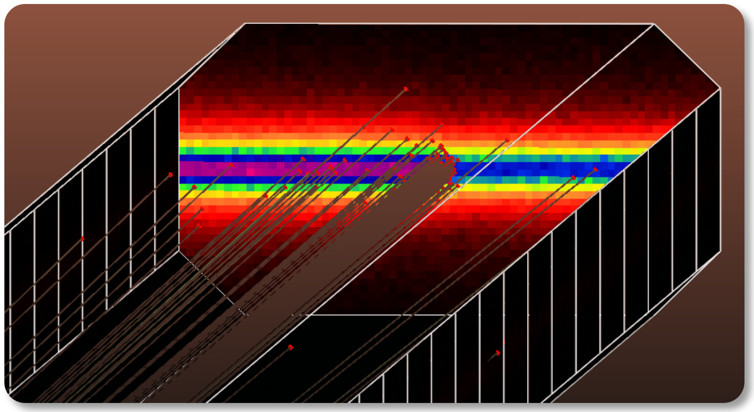
Magnetic elements in **orange**, program generated synchrotron fan in **green**, surface hit points in **red**

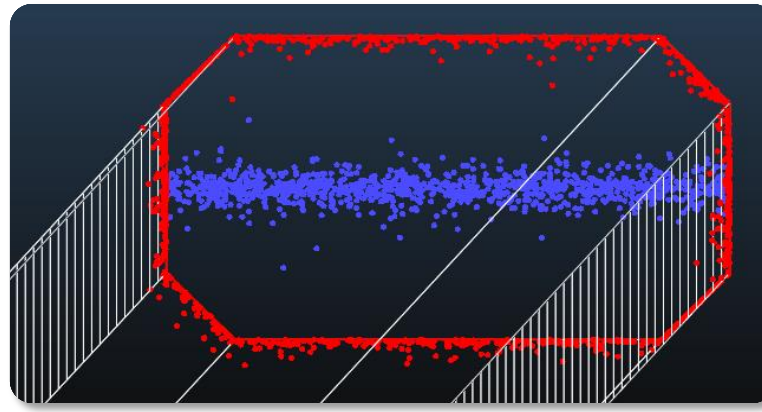
APS-U storage ring vacuum system design using SynRad/MolFlow+ with photon scattering

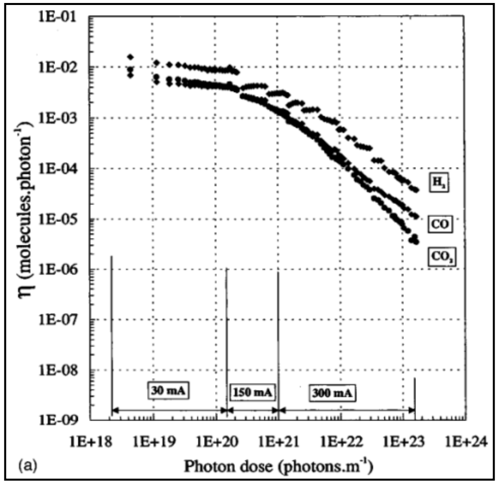
Jason Carter, AVS 2015 presentation

Coupled simulations

- Coupling feature translates SynRad flux density rates (photons/cm^2/s) to photon stimulated desorption, PSD, outgassing (mbar*L/cm^2/s)
- Translations based on conditioning time and PSD yield measurements for various vacuum materials







APS-U storage ring vacuum system design using SynRad/MolFlow+ with photon scattering

Manpower 2017

Individual	Institution	Percentage in %	Task
Alexandre Camsonne	Jefferson Lab	20	Wakefield, general,postdoc supervision
David Gaskell	Jefferson Lab	5	Geant3, laser system,postodoc supervision
Joshua Hoskins	U. Manitoba	50	GEMC full simulation
Michael Sullivan	SLAC	advisory	Synchrotron
Haipeng Wang	Jlab SRF	advisory	Wakefield
Robert Rimmer	JLAB SRF	advisory	Wakefield
Christophe Royon	Kansas U.	5	Detector, electronics, Wakefield
Nicola Minafra	Kansas U.	5	Detector, electronics, Wakefield
Michael Murray	Kansas U.	5	Detector, electronics, Wakefield

Draft FY2018 Budget

	K$ direct	Total Cost With overhead K$	Cumulative
Post doc	33	51	
Travel	15	23.175	74.175
CST license	7	11	85.175
Amplifier	20	30.9	116.075
Discriminator	20	30.9	146.975
Lower chamber	10	15.45	162.425
Detector holder	7.5	11.5875	174.0125
Test flange	5	7.725	181.7375
Total	149.5	181.7375	

Simulation, HOM

Amplifier and Discriminators for efficiency test

Test full detector

Conclusions

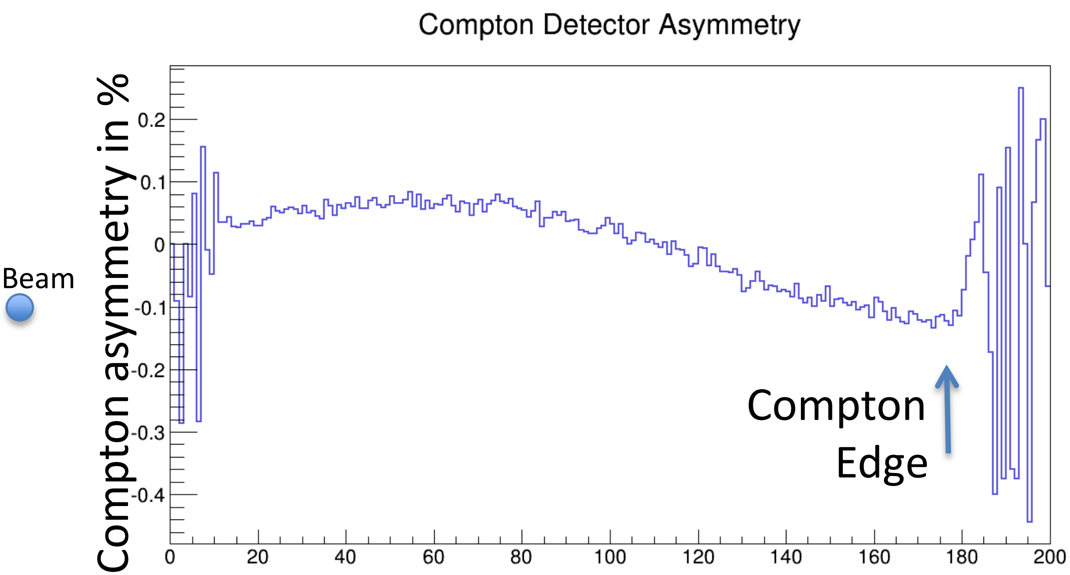
- Full simulation running on farm : high statistics with full setup on going
- Synchrotron radiation can be a significant problem but solved with chamber design
- Preliminary RF HOM power gives 2.5 kW

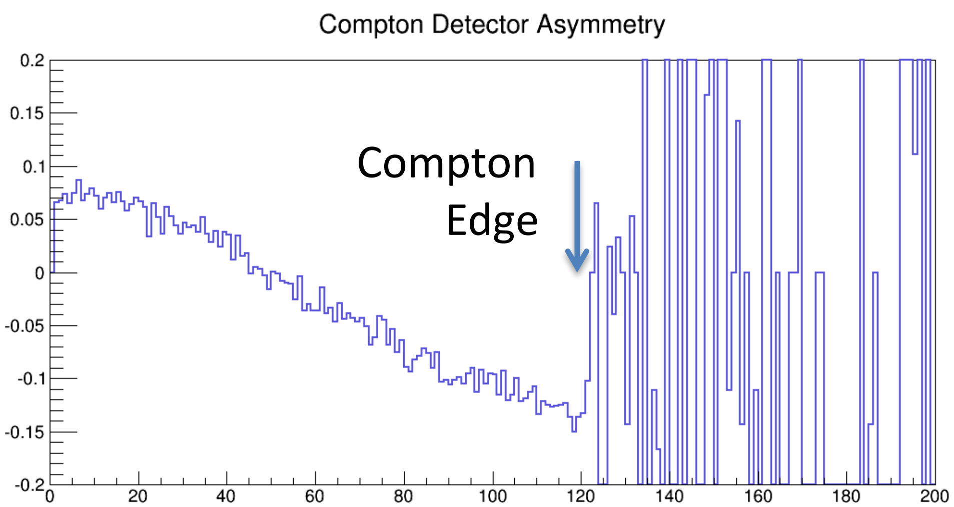
No show-stoppers for Roman Pot option

- Test stand started :amplifier and DAQ
- Next proposal :
  - Continue simulation and optimization of detector
  - Test bench : test to check timing and efficiency with full setup similar to setup that will be used in beam
  - Vaccum modelling and background studies

Backup

Compton Asymmetry



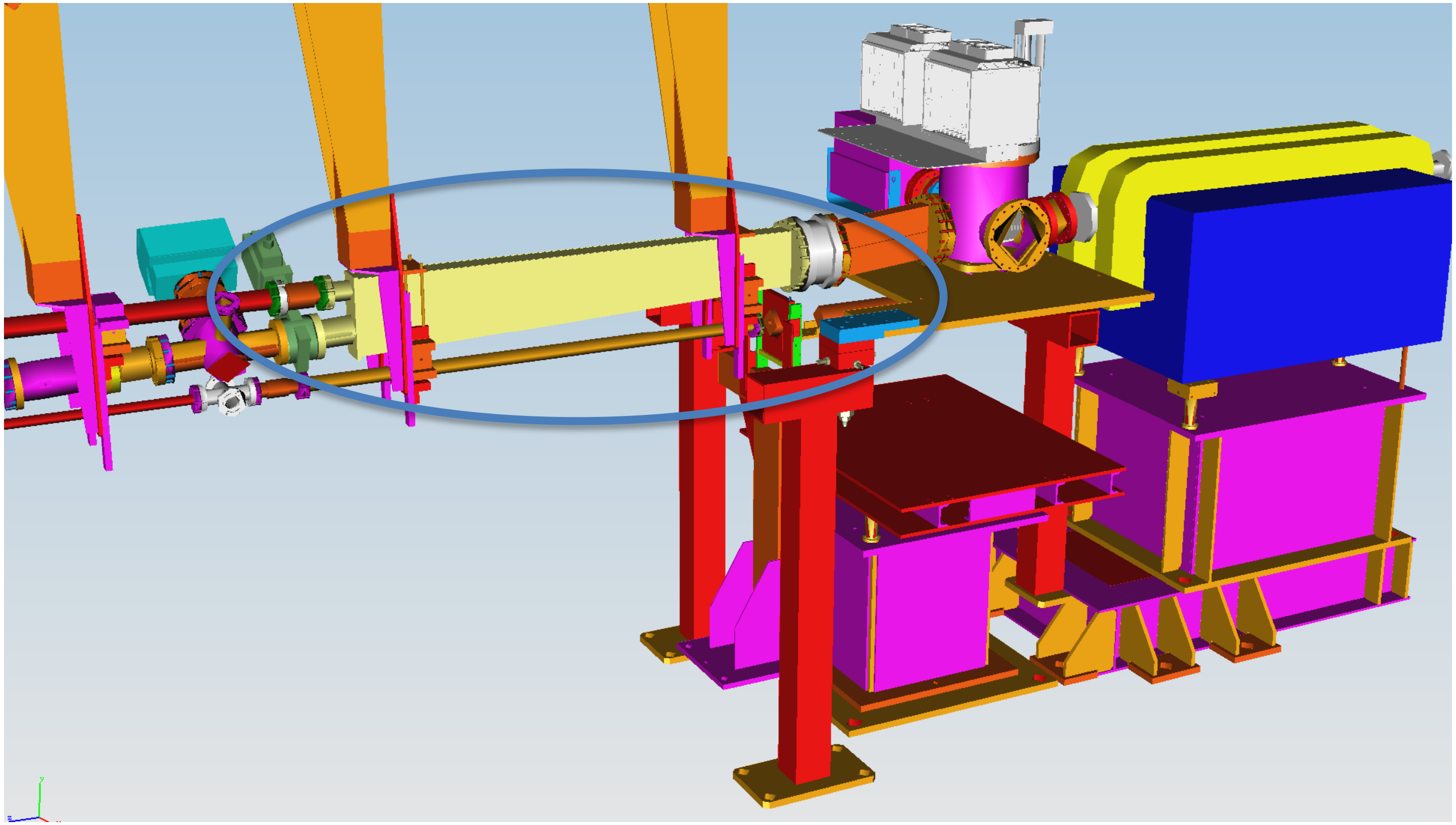


- Discrepancy of amplitude of asymmetry (smaller than expected)
- Check with Richard, BNL generator looks fine
- Suspect input file generation or analysis script

- Asymmetry with new generator looks good and agrees with Geant 3 simulation and theoretical value

- Optimize event generator for better efficiency

HallA Compton chamber setup



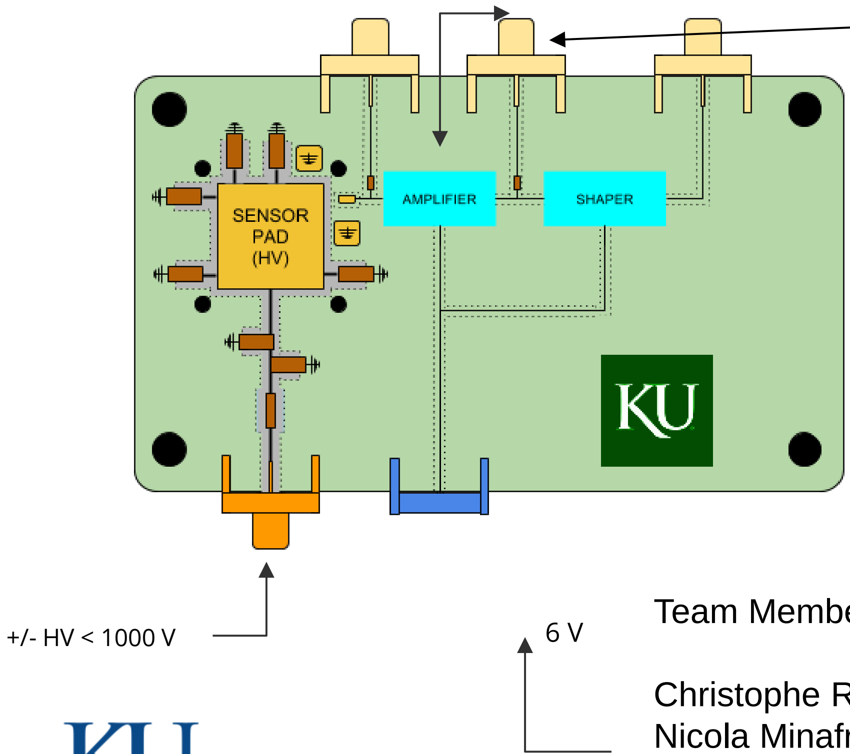
- Put a similar chamber after 3rd dipole of chicance (before electron detector.
- Starting point for future studies

New Amplifier Concept

Original Design

A one channel board that can be use for the characterization of different solid state detectors.

- Sensors can be read-out using an external amplifier
- The amplifier can be characterized by injecting an external signal
- The 0 resistor can be removed during normal operation



- The first stage is a Charge Sensitive Amplifier
- The second stage is optimizing the output for timing measurements

Sensors up to 20x20 mm^2 can be glued and bonded.

The components can be easily changed to accommodate:

- Diamond sensors: ~1 nA bias current, both polarities, small signal
- Silicon detectors: ~100 nA bias current, small signal
- UfSi: ~100 nA bias current, ~ larger signal
- SiPM: ~ 5 uA bias current, large signal

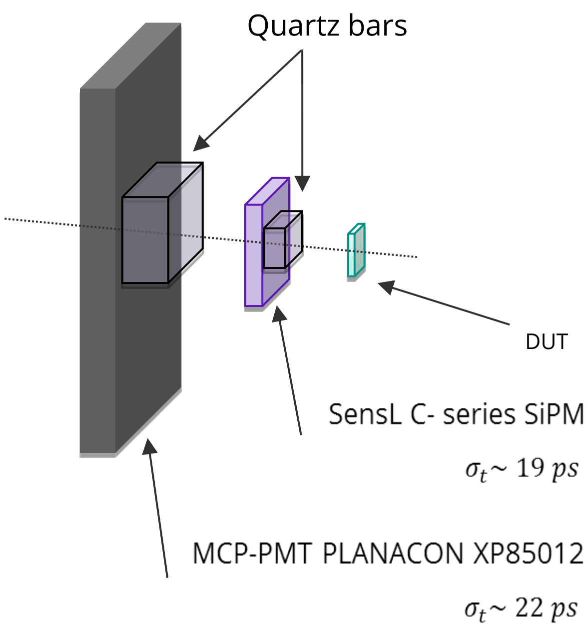
Team Members:

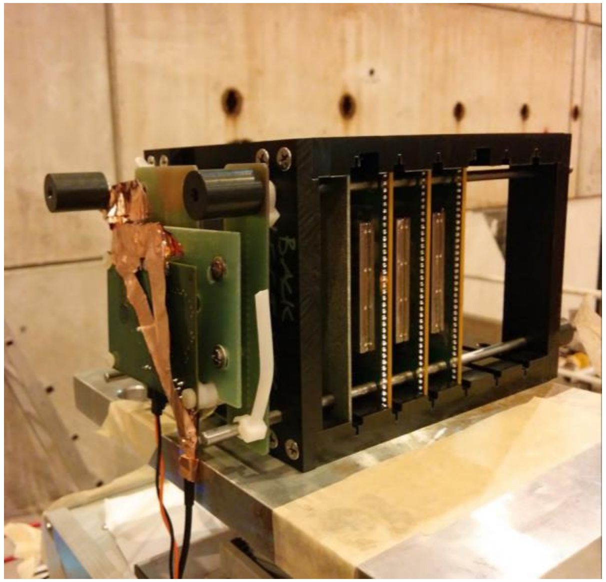
Christophe Royon
Nicola Minafra
Hussein Al Ghoul

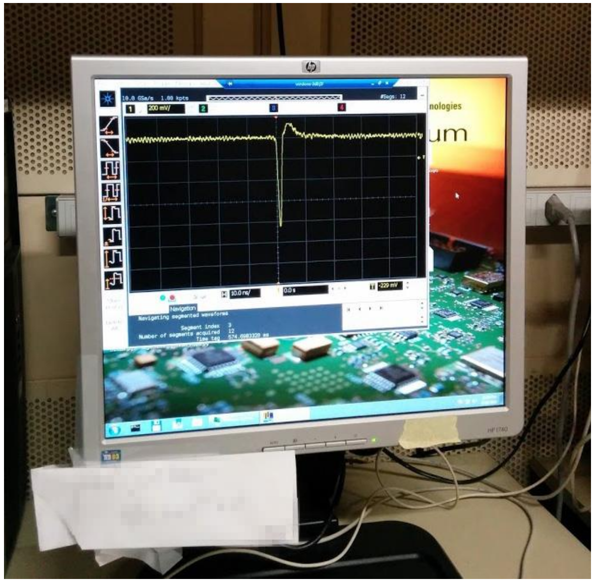
New Amplifier Testing

Test beam in the north CERN area

The time resolution was measured using a SiPM and a MCP-PMT with Cerenkov bars as time reference







The detector was installed on the beam in the H8 area[1] using a pre-aligned structure[2] and was acquired using a remote controlled oscilloscope: Agilent DSO9254A, 8 bit at 20 Gsa/s

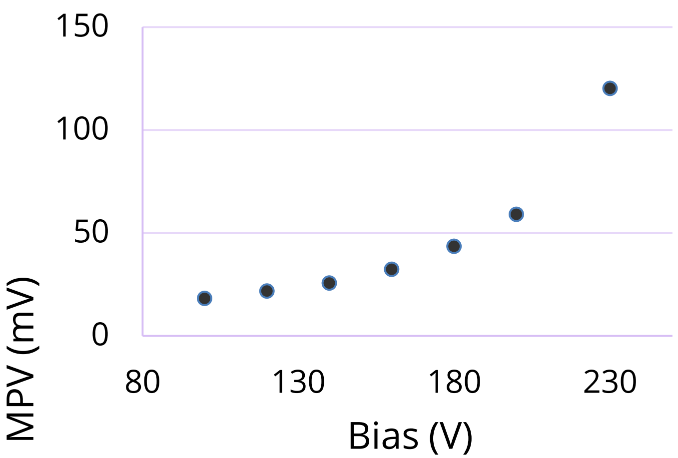
All the tests were conducted at room temperature.

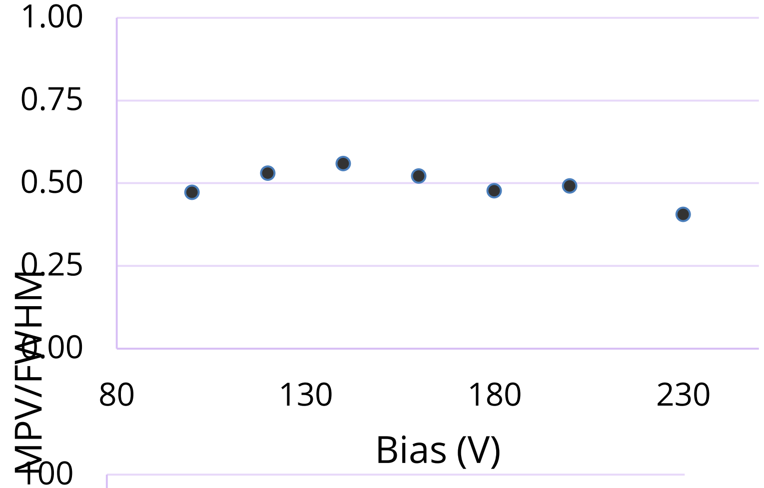
1: Thanks to the TOTEM Collaboration
2: Thanks to N. Cartiglia et al. : arXiv:1608.08681

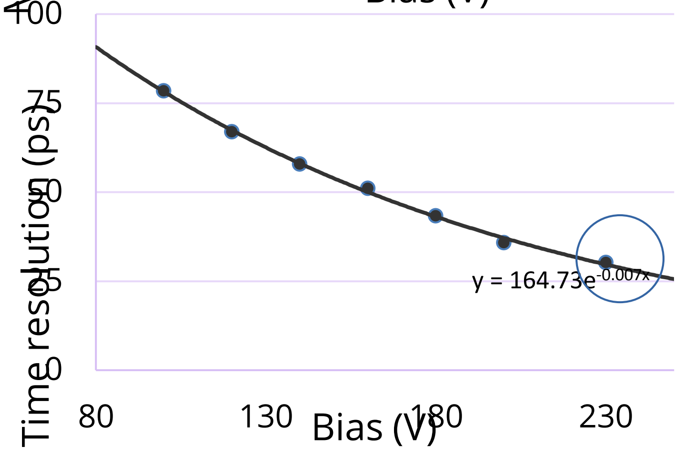
New Amplifier Testing

Performance VS Bias voltage

A time resolution below 30 ps was obtained, in stable running conditions, using an off-line Constant Fraction Discriminator.





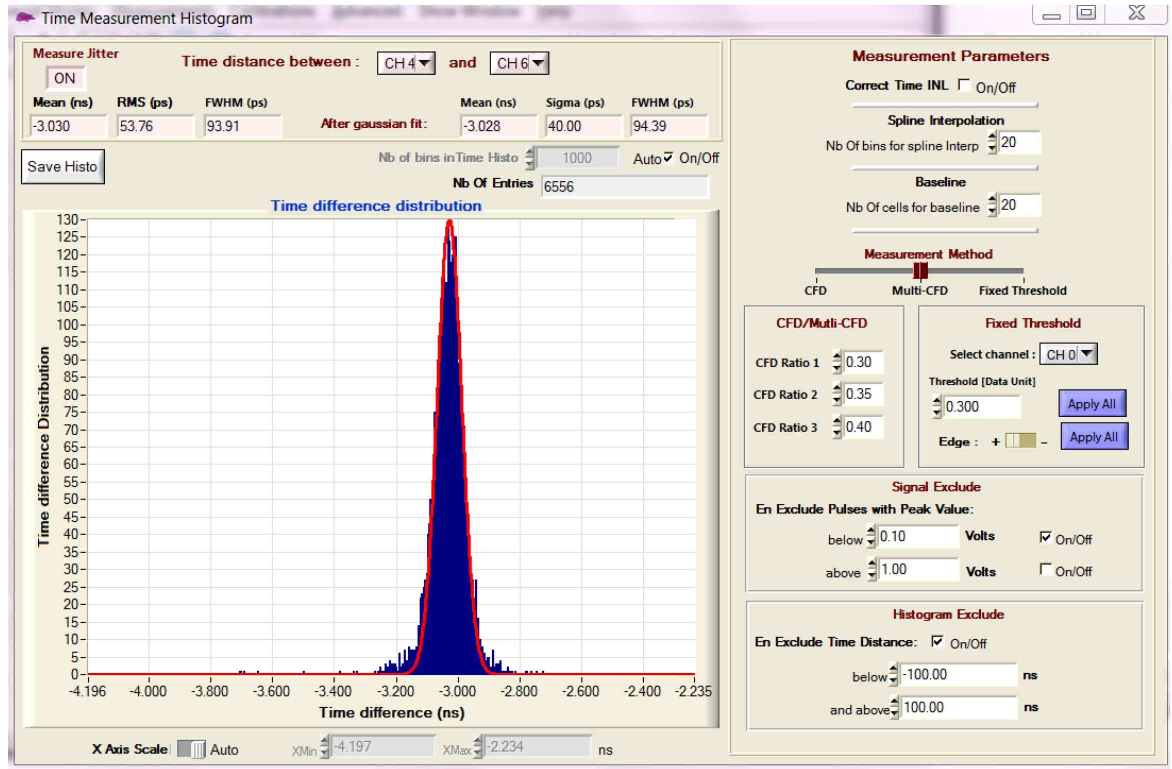


The sensor’s gain clearly increases when the bias voltage is increased

The sensor’s dark current is above > 1uA when the bias voltage is above 230V

New Amplifier Testing

Time difference measurements using a SAMPIC



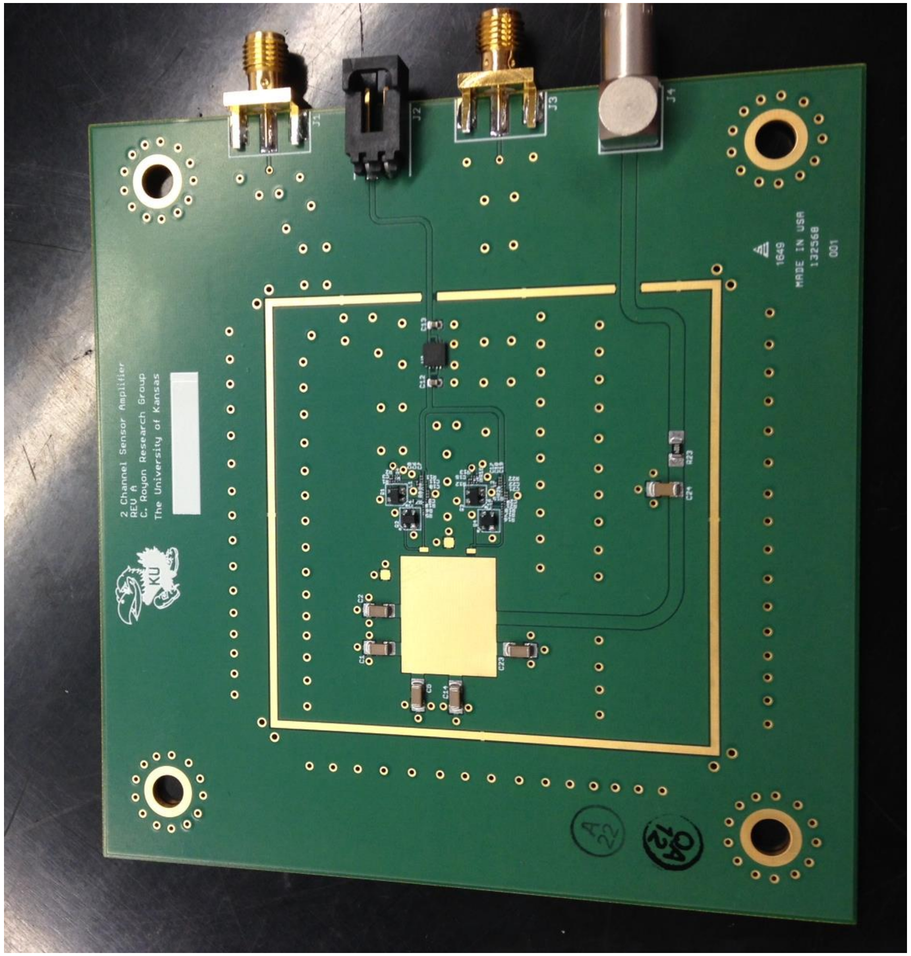
The SAMPIC requires a calibration procedure, a preliminary result suggest that the performance are 1% worse than the oscilloscope:

$$\sqrt{(19 + 1\%)^2 + (35 + 1\%)^2} \sim 40.2 \text{ ps}$$

SiPM

UfSD

Detector amplifier



- Good performance of discrete amplifier
- Can use as base for multichannel ASIC